The Johns Hopkins University
Applied Physics Laboratory
Laurel, Maryland

Navigation (Orbit Determination) Status

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- **Navigation Challenge**
  - **No ranging assumed**
  - **Singular Doppler data provides one DOF (range-rate)**
  - **Station motion over one day provides two DOF (longitude)**

  - **Observation of orbit differences over long periods**
    plus: force model
    yields: complete state vector solution

  - **Need change in Doppler data over time**
    STEREO in nearly identical Earth orbit
    Fitting arcs very long (weeks or months)
    Hi-fidelity radiation pressure model needed
    Requirements: Dynamic cross-sectional area model
    Attitude information

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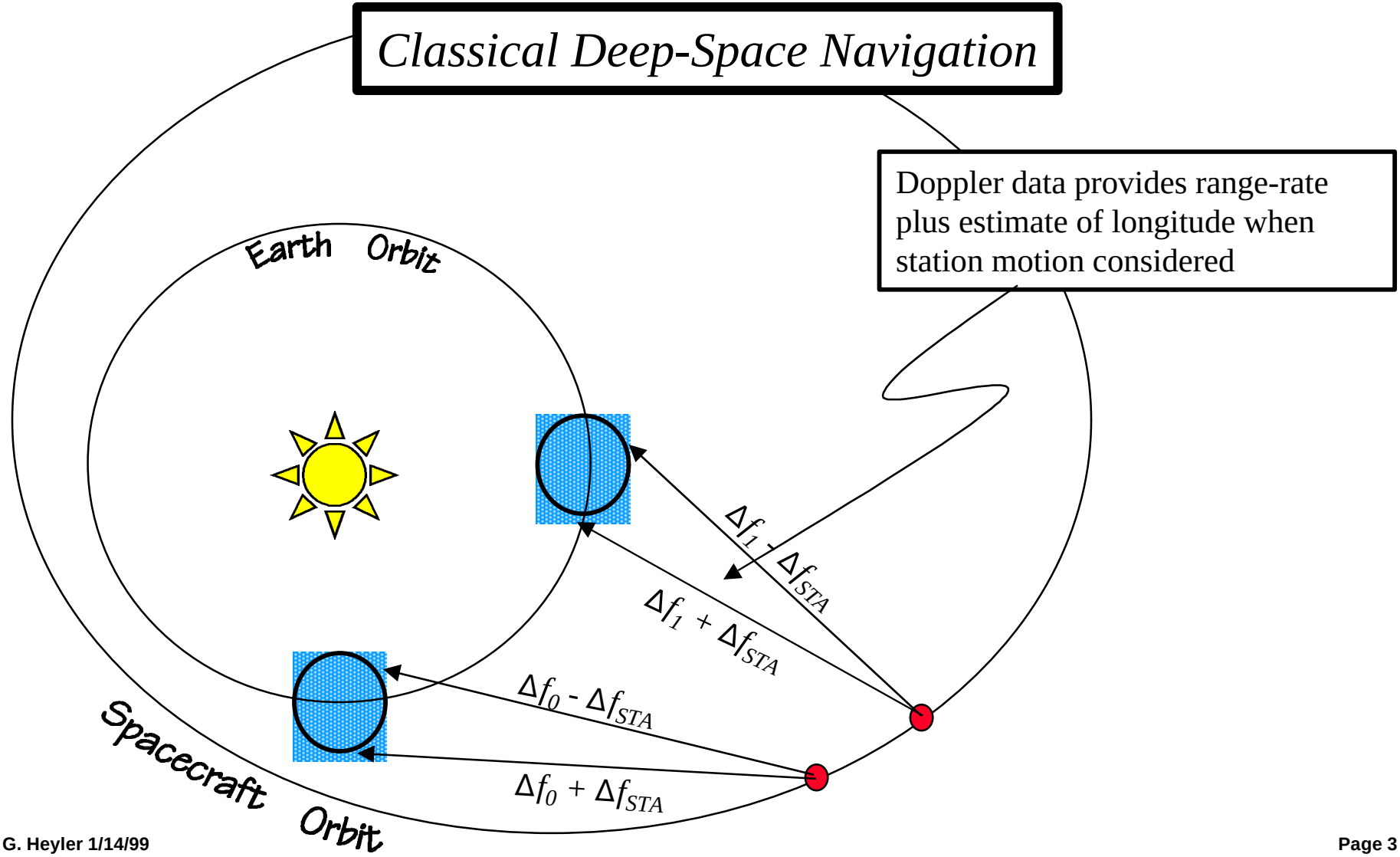
Classical Deep-Space Navigation

Doppler data provides range-rate plus estimate of longitude when station motion considered



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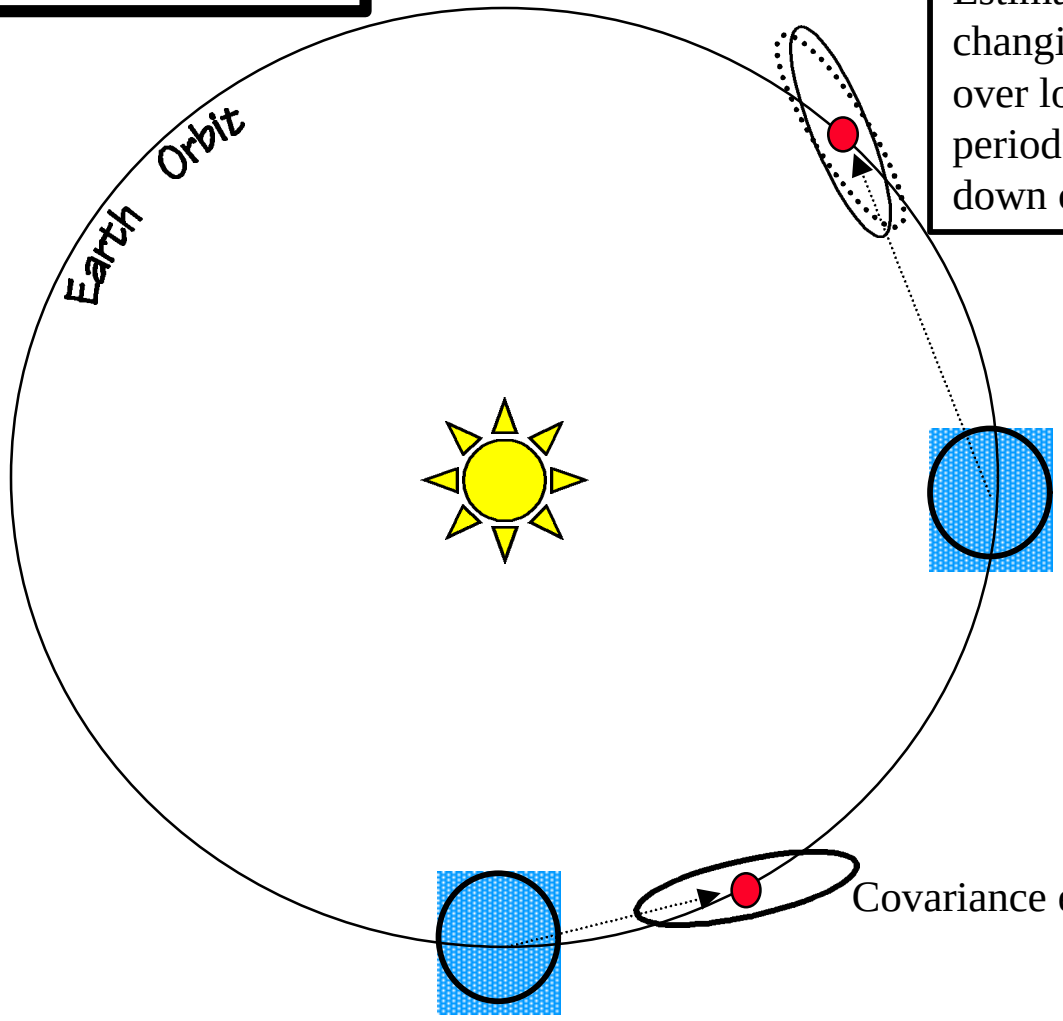
Doppler only method



Estimates of changing direction over long time periods slowly drives down covariance

Solar STEREO Navigation

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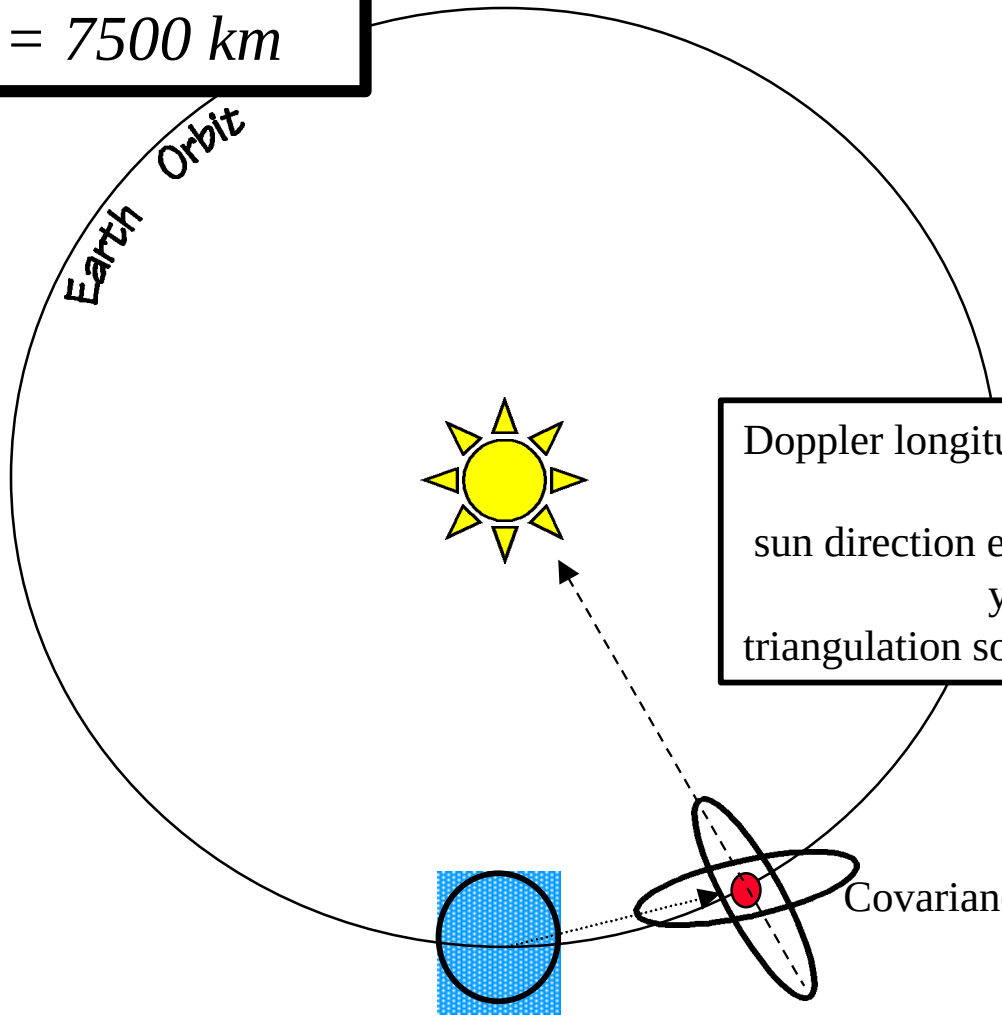
Doppler with sun angle,
50 μrads = 7500 km



- **Spacecraft Sun angle data**
  - **Triangulation method determines Earth --> probe range**
  - **Convergence time drops from weeks/months to hours/day**
  - **Minimizes need for hi-fidelity radiation pressure model**
  - **Possibly good to 50 rads, would meet 7500 km requirement**
  - **Inclusion in ground processing filter**
  - **Needed for any onboard autonomous nav experiments**
  - **Not a requirement now (pending simulation), strongly desired**

- **Navigation ground software options**
  - **Develop in-house**
    - **Labor intensive**
    - **Duplication of decades of effort**
    - **Validation / verification**
  - **Acquire/[modify] existing systems; considering:**
    - **GTDS - Goddard Trajectory Determination System**
    - **OCEAN - Orbit Covariance Estimation and Analysis**

GTDS - Goddard Trajectory Determination System

- **Old reliable, currently used on ~40 missions**
- **Vintage 1970's, batch, mainframe, Fortran, card punch format**
- **Installed and tested on APL Unix machines**
- **Source code, makefiles transmitted to APL, no known license problems**
- **Documentation delivered, 7.25 inches thick**
- **Ephemeris generator, orbit determination, test generation modules**
- **Hi-fidelity solar system and atmospheric models**
- **Someone needs to get intimately familiar with it**
- **Determine modifiability - interfaces, solar data???**

OCEAN - Orbit/Covariance Estimation and Analysis

- **Developed by Naval Research Lab (circa 1995, ongoing)**
- **Backup support for 12 operational LEO satellites (automated)**
- **Prime support for NEMO**
- **Executable and documentation (no source) to be provided to support TIMED Guidance and Navigation System (GNS) validation**
- **Supported on DEC (VMS, Ultrix) and SGI (IRIX)**
- **Batch or filter based estimation (method is observation type dependent)**
- **Hi-fidelity solar system and atmospheric models**
- **Determine modifiability**